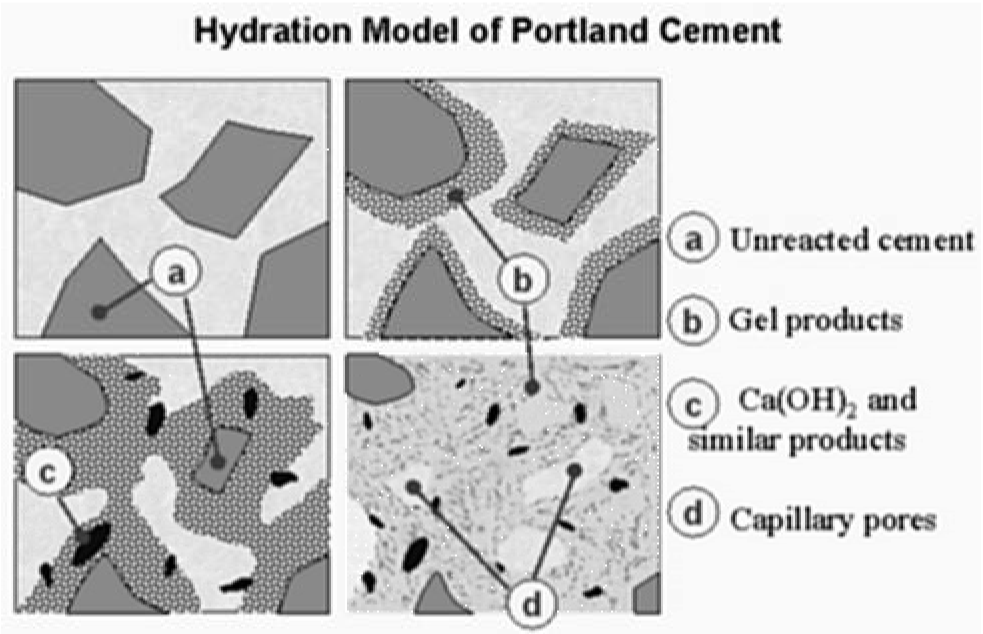
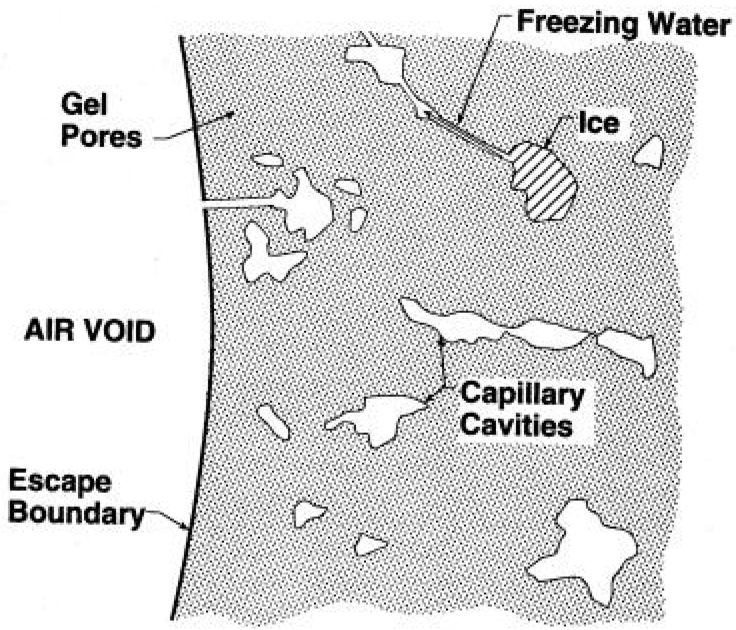
Why Air Entrainment is Important to Concrete

Air entrainment is critical to the freeze-thaw resistance of concrete. Poor air systems have been noted as the main initial cause of early deterioration in Iowa pavements.

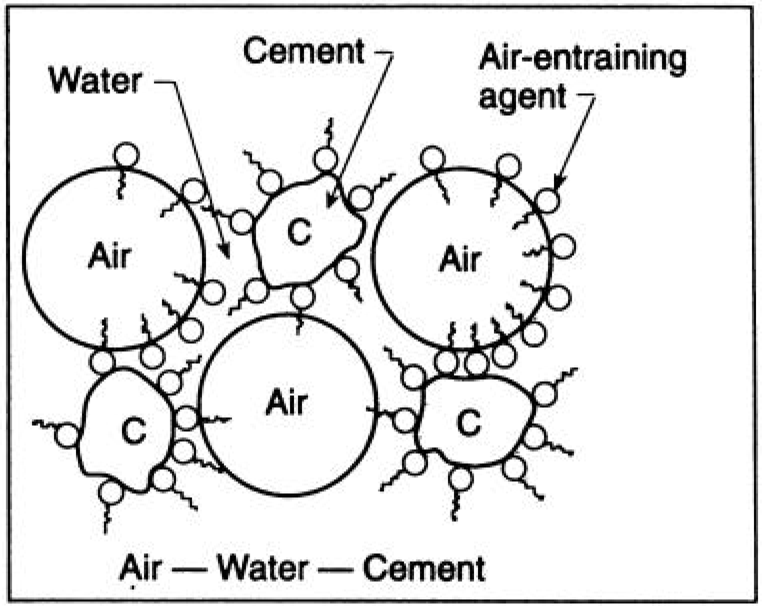


Concrete is basically a porous material. After the original mix water is used up in the chemical reaction called hydration, most of the remaining water is lost by evaporation leaving behind the capillary pores.



When concrete is exposed to moisture, water moves through the concrete in these pores. When the temperature drops below freezing, the water turns to ice. Ice occupies 9 percent more volume than water. The expanding ice forces the water through the capillaries as it freezes. The repeated freezing and thawing can damage concrete and deterioration is increased with the use of deicing salts. Air voids act as a pressure relief for the expanding water and ice.

The resistance to freeze-thaw damage depends upon the size and distribution of the voids, along with the degree of saturation. Many smaller voids separated a short distance provides the greatest degree of protection.



Air entraining agents are added to aid in the stabilization of the air voids by reducing surface tension in the water. Also, the one end of the air agent molecule is attracted to air and the other is attracted to water and thus to cement grains, thereby allowing a coating of calcium to form around each air bubble, making them more stable in plain water.

Many factors can affect the ability of a concrete mixture to produce an adequate entrained air system. Attached is an overview of effects of materials and production processes on the control of air in concrete.

Factors Affecting Control of Air in Concrete

Category	Characteristic	Effects	Guidance
Cement	Alkali Content	Air content increases with increased alkali content	Dosage may be reduced up to 40% for high alkali cements
		Very low alkali cements (less than 0.3%) reduces air content	Dosage may need to be increased by 100%
	Fineness	Air content decreases with increased fineness	Dosage may be increased up to 100% for Type III cements
	Blended Cements	As fineness of cement increases air content decreases	Increase dosage rates of up to 100%
		Air content decreases with increase in LOI	Increase dosage rates of up to 100% or more
	Content	Air content decreases with increased amount of cement	Increase dosage as cement content increases
	Admixture Compatibility	Rapid slump loss is observed when a cement containing anhydrite is used in conjunction with a lignosulfonate based water reducer - hard to control air content	Use a retarding type admixture. Delay addition of water reducer by 15 secs. Increase mix time

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Category	Characteristic	Effects	Guidance
Mineral Admixtures	Fly ash (LOI)	Air content decreases with higher LOI (carbon content) Carbon adsorbs the air agent reducing effectiveness	LOI's may vary as the peak load at the power plant causing variability load to load
		Air may be unstable with some combinations of fly ash, cement, and AEA's	Prepare trial mixes and evaluate air
		LOI's greater than 1%	Usually increases AEA demand
		LOI's greater than 2% may cause air to be very unstable over time	May increase AEA demand 5 times or more. May not be able to stabilize entrained air or attain required amount of air
		Finer fly ashes decreases air content	
	GGBFS	Air content decreases as GGBFS fineness increases	May need up to 100% or more AEA with finely ground slags
	Silica Fume	Air content decreases with increase in silica fume content	May need up to 100% increase in AEA
Chemical Admixtures	Water Reducers	Air content increases with increase water reducer dosage rates (lignin-based water reducers)	Reduce AEA dosage by up to 50%
	Retarders	Similar to water reducers	Reduce AEA dosage

Factors Affecting Control of Air in Concrete

Category	Characteristic	Effects	Guidance
Aggregates	Maximum Size	Air content requirements decrease as maximum size increases (up to 1.5") Well graded aggregates aid in retention of smaller entrained air bubbles	Total air content required to protect concrete decreases Monitor gradations
	Sand	Air content increases with increased sand content	Decrease AEA content
	Sand Grading	Increased amounts retained on No. 30 to 50 sieves promote air entrainment Increased amount of fines passing the No. 100 sieve will decrease air content Organic contaminants may result in large fluctuations in air	Monitor sand gradations Monitor sand gradations Use clean sands
	Moisture Absorption	Many coarse aggregates are highly absorptive. Some will indicate moisture and still absorb water from the mix.	Manage stockpiles - moisture contents can vary load to load causing increases and decreases in slump and air content
	Minus No. 100	Increased amounts of crushed fines decreases air content Clay or silt fines in sand decrease air content Combined totals greater than 2% may decrease air contents Combined totals greater than 2.5% will decrease air contents	Total combined of greater than 2% passing the #100 sieve will affect ability to entrain air May require dosage increases up to 5 times

Factors Affecting Control of Air in Concrete

Category	Characteristic	Effects	Guidance
Water	Hardness	Batching air agent with hard water or wash water first will decrease air content	Increase AEA by up to 50%
	Organic Contaminants	May increase or decrease air	Test water before using if not potable
	w/c ratio	Air content increases with increase in w/c ratio	1 gallon water = 0.5 to 1" slump
	Slump	Increase in slump increases air content (Up to 6 in.) Increase in slump to greater than 6 in. decreases air content Difficult to entrain air in low slump concrete (less than 1in.)	Increase slump 1" -increase air 0.5% Increase slump

Factors Affecting Control of Air in Concrete

Category	Characteristic	Effects	Guidance
Production	Batching Sequence	Simultaneous batching may lower air content Batching AEA on to cement reduces AEA effectiveness Blending all materials promotes better mixing and entrained air development	Discharge AEA into water or water line or on to sand
	Mixer Capacity	Air content increases as capacity is approached Overloaded mixer decreases air content	Run 80 to 85% of capacity gives best mixing action
	Mixing Time	Air content increases up to 5 min. mixing (central plant) Air content will decrease after 20 minutes of mixing (transit) Mixing times less than 60 seconds may not develop proper air void system for freeze thaw protection	1 to 3 min. mix time optimum for central
	Mixing Speed	Air content increases to 20 rpm and decreases as speed increases	
	Admixture metering	Accuracy and reliability of dispensing system affects uniformity of air Add all chemical admixtures separately	Visually check bottles for accuracy

Factors Affecting Control of Air in Concrete

Category	Characteristic	Effects	Guidance
Placement Procedures	Transport and delivery	Transport in non agitated equipment worse than for agitated	When using non-agitated haul units use smoothest and shortest haul routes
	Haul Time	Loss of 1 to 4 percent air depending on time Worse in hot weather	Use haul route that results in shortest time
	Mixing Drum	Air content decreases as mixer blades are worn or if concrete has hardened on or around the blades and pedestals	Perform regular maintenance
	Belt Conveyors	Reduces air content by up to 1 percent for less than 3000 ft.	
	Pumping	Pumping can lose up to 4% air	Don't allow high vertical drop Distance, slump, and line pressure all affect air content
	Vibration	Air content decreases under prolonged vibration at high frequencies (>10,000 vpm)	Closely spaced vibrators recommended 8000 vpm max. internal vibrators
	Finishing	Air content reduced in surface layer by excessive finishing	Avoid finishing with bleed water on surface DO NOT add water to surface to finish
	Temperature	Air content decreases with increasing temperature In low slump concrete (< 2 in.) at a temperature above 90 F is has been found to be more difficult to hold the slump and increase air contents. Likewise a small amount of water generates larger slump gains and a larger entrained air increase for concrete at 70F	Watering of stockpiles will help cool coarse aggregate and reduce absorption of mix water Utilize coldest water possible for Hot Weather Concreteing (well water)